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Outlook for Energy and Implications for Irrigated Agriculture

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OUTLOOK FOR ENERGY AND IMPLICATIONS FOR IRRIGATED AGRICULTURE

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Introduction

Agriculture uses large quantities of energy to pump groundwater for irrigation. This means the cost of energy has important implications for the industry in terms of costs and profitability. Increases in the prices of energy sources such as natural gas, electricity, liquid petroleum gas and diesel can cause economic hardship for irrigators, particularly if those increases are unanticipated. The purpose of this paper is to briefly summarize important trends in the current domestic energy situation that could have significant impacts on the future cost and availability of energy, and to show what the implications of those trends are for irrigated agriculture. The primary focus of this study will be on trends in natural gas, since natural gas is the major fuel used for irrigation in the Great Plains states.

The Energy Situation

This section is designed to give a very brief overview of the energy situation in the United States. The material is drawn primarily from published reports. Some general indications of consumption, supply and price of energy provide a basis for investigating the future of irrigated agriculture.

The Arab oil embargo of 1973 focussed massive attention toward what is commonly called the "energy crisis". References to the current energy situation frequently express the misconceived idea that the energy crisis appeared overnight as the direct result of collusion on the part of members of the OPEC cartel. Although the OPEC nations did cause the world price of oil to skyrocket, they could not have had such a profound influence on price had it not been for the cumulative effects of forces in the domestic energy market which had been gaining momentum over a number of years. The large energy price increases of the mid-1970's were merely the most visible symptoms of a much larger problem.

The energy problem is fundamentally economic in nature. In its simplest form, the problem can be characterized as one of supply and demand. Over the past several years, domestic consumption of energy has far exceeded domestic production of energy, putting pressure on prices and causing consumption of imported energy to rise. Demand for energy has been spurred by rising income, increasing use of machinery and other factors associated with economic growth. Production, on the other hand, has been retarded by rising exploration and development costs concurrent with government price regulations. Even the import situation has been affected by economic forces exerted by the oligopolistic OPEC cartel.

To point out important factors contributing to the current energy situation, it is useful to examine trends in the consumption, production and price of energy in the United States. Using this energy base, the analysis will be extended to some of the effects that adjustments in the energy sector will have upon irrigated agriculture.

Trends in Consumption

Domestic energy consumption grew at an annual rate of 3.6 percent during the twenty years prior to the 1973 Arab oil embargo [Federal Energy Administration, 1976]. A number of factors contributed to the steady growth of consumption. The most important factors were economic growth, the low prices of fossil fuels and the abundant supply of fossil fuels over most of the period before the embargo. Of the above factors, the low price and plentiful supply of fossil fuel did the most to encourage increased usage of energy. Furthermore, those two factors provided little or no incentive to use energy in the most efficient manner, thus high levels of energy use became part of the American lifestyle.

Even though domestic production lagged behind domestic consumption for decades before the Arab embargo, there was little need to economize on the use of energy since there was an abundant supply of foreign fuel at low prices. Thus America gradually increased not only its consumption of energy, but also the proportion of that energy purchased from foreign sources. By 1973 the United States imported 33 percent of its petroleum from foreign countries. The embargo ended the era of cheap energy by restricting the world supply of petroleum, upon which the United States and the rest of the world had become so dependent. The world price of petroleum rose 365 percent in a single year [Council of Economic Advisors].

Prior to the embargo, the world price of oil was $4.54 per barrel. The price has since risen as high as $14.66 per barrel (Oct. 1975), although it has fallen slightly during the past year. The higher price of petroleum, coupled with a general economic slump, has caused energy consumption during 1974 and 1975 to decrease slightly from an all time high of 74.8 quadrillion BTU in 1973, to 72.0 quadrillion BTU in 1975 [Council of Economic Advisors]. Most of the decline in energy consumption was accounted for by diminished use of petroleum products in response to significantly higher prices. As consumers of petroleum adjust to the new price levels and the economy begins to revive, the consumption of

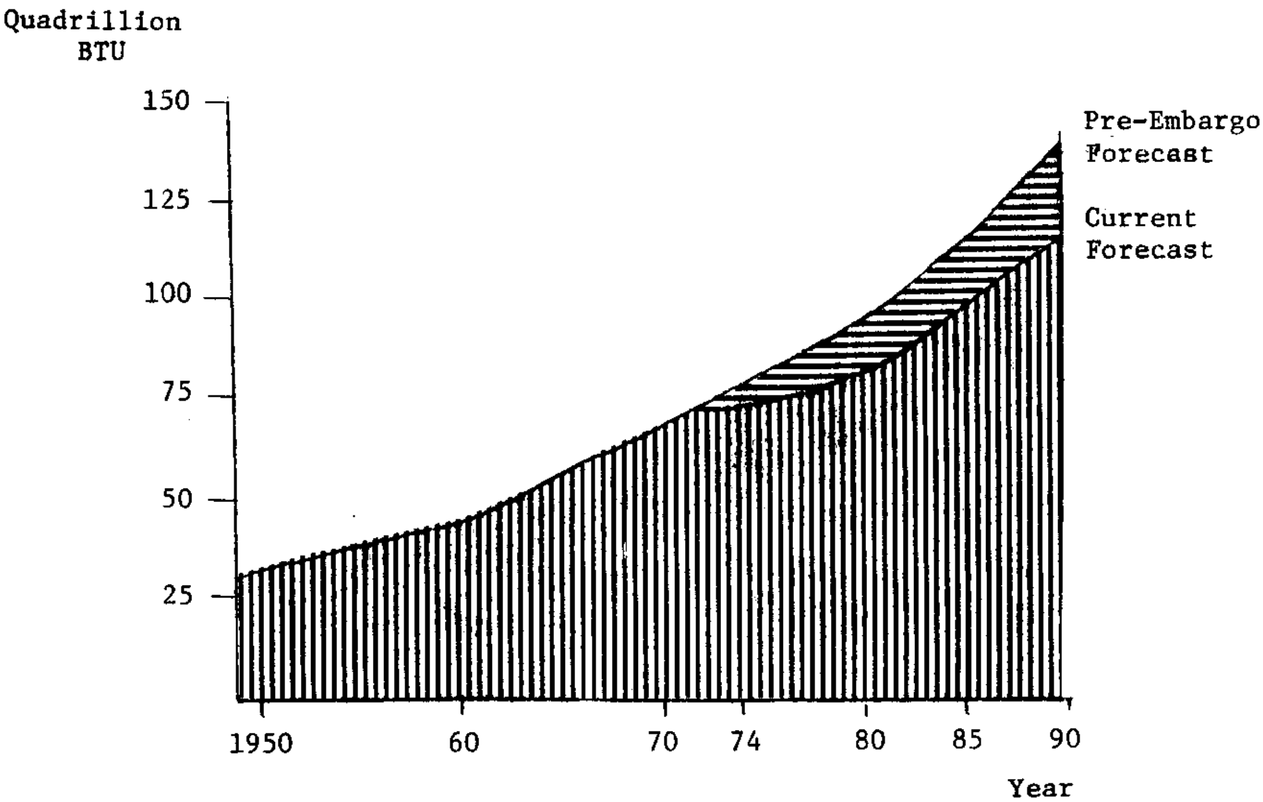

Figure 1. Historical and projected annual energy consumption, United States

Source: Federal Energy Administration, 1976 National Energy Outlook, United States Government Printing Office, Washington D.C., 1976.

energy is expected to resume its upward course but at a significantly slower rate than before the embargo [Federal Energy Administration, 1976]. The Federal Energy Administration projects that the growth in domestic energy consumption will slow to an annual rate of 2.8 percent provided the world price of oil does not fall appreciably and the Federal government does not attempt to regulate domestic energy prices. The effect of higher prices on energy consumption is shown in Figure 1. The area between the pre-embargo forecast and the current forecast represents the amount by which domestic energy consumption is expected to be reduced as the result of higher energy prices.

In addition to slowing the rate of growth in energy consumption, higher petroleum prices will change the pattern of energy usage. Currently fossil fuels such as coal, oil and natural gas, supply 94 percent of the energy consumed in the United States. However the consumption mix relies heavily on oil and natural gas to provide 76 percent of the energy used, even though those two fuels comprise only 7 percent of the United States' energy reserves. Conversly, coal, which constitutes 90 percent of the nation's recoverable energy reserves, is called on to supply only 18 percent of annual consumption [Federal Energy Administration, 1976]. Higher petroleum and natural gas prices will encourage the substitution of more plentiful fuels, like coal, for oil and gas which are relatively short in supply. Also, higher energy prices will stimulate the development and adoption of alternative energy sources such as shale oil, nuclear and solar power, and synthetic fuels.

The Department of the Interior, Bureau of Mines projects that by the year 2000 fossil fuels will supply only 65 percent of domestic energy consumption, as compared with 94 percent today. Figure 2 gives some in-

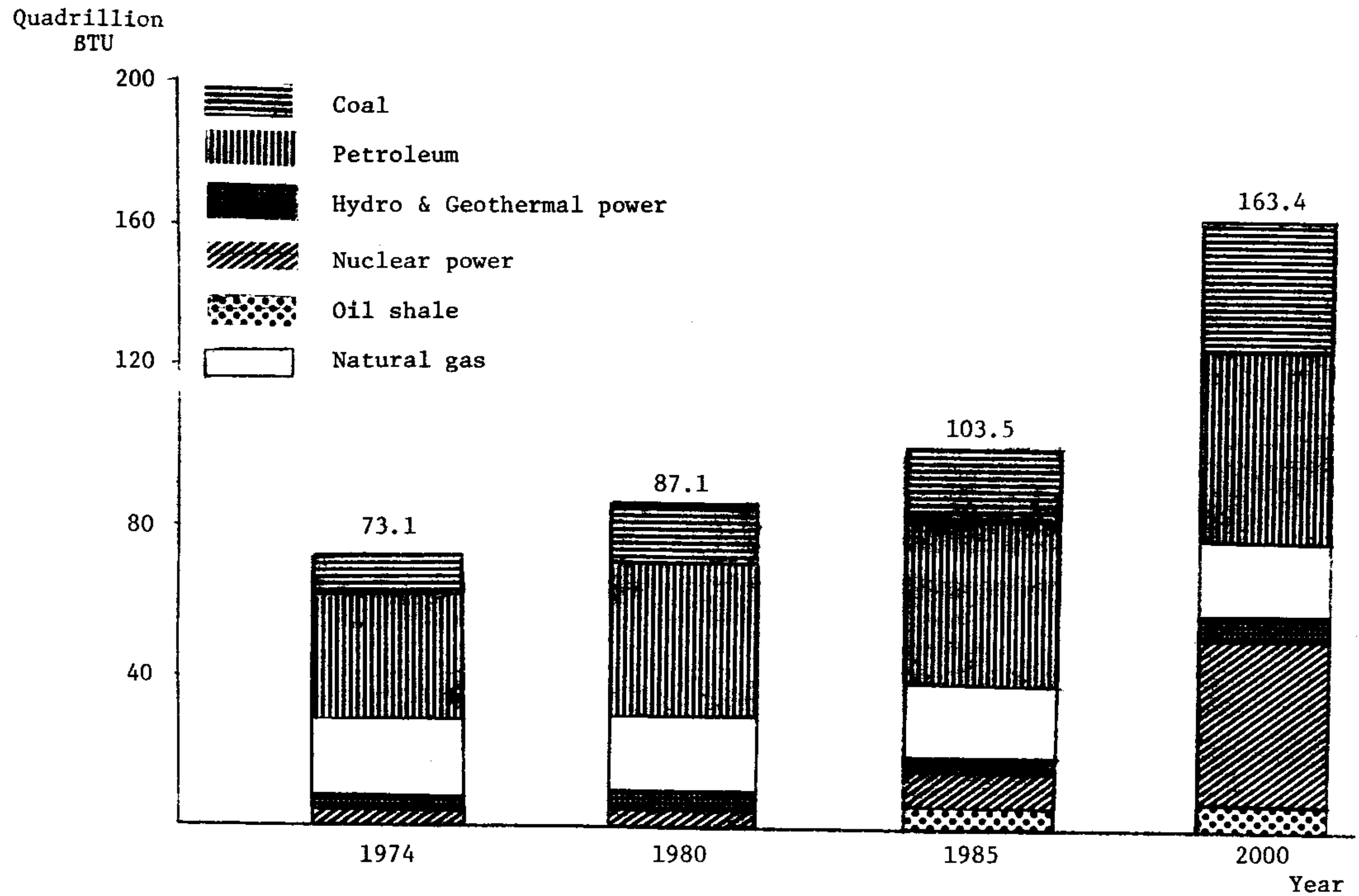

Figure 2. United States energy consumption by source: 1974-2000

Source: Department of Interior, Department of Bureau of Mines, United States Energy to the Year 2000 (Revised 1976).

dication of the change in the pattern of energy consumption which is expected if current energy trends continue. The figure indicates that nuclear power will increase its share of energy provided from its current level of 1.6 percent ot 28.7 percent by the year 2000. Coal's contribution is expected to rise from a level of 18 percent in 1974 to 31 percent in 2000, while petroleum's share shrinks from 46 percent to 31 percent and natural gas' share falls from 30 percent to 12 percent. These changes will not be frictionless. Development of new energy sources will entail higher costs and have implications on environmental quality. Furthermore these changes could affect water usage and availability in certain parts of the United States. Discussion of the implications on water usage entailed by the development of new energy sources is addressed later in this paper.

The growth of two energy sources which are used heavily in irrigation, electricity and natural gas, has been faster than that of energy in general. Electricity consumption has grown at twice the rate of aggregate energy consumption (about 7 percent per annum), and is expected to continue to grow twice as fast in the future, but at the reduced level of 5.4 percent reflecting higher energy prices [Federal Energy Administration, 1976]. Growth in the demand for electricity stems from several factors. First, electricity can be generated using a large number of alternative fuels, ranging from natural gas and oil to nuclear and solar power. Second, electricity use is relatively pollution free. Third, electricity is a versatile power source, easily adapted to uses in industry and households. Finally, until the last few years the cost of using electricity has been falling [Federal Energy Administration, 1976].

Electricity is, however, considerably more expensive than primary power sources because: (1) other fuels are expended in its generation, (2) much of the energy used in generation is lost due to mechanical inefficiency, and (3) large amounts of expensive capital equipment are necessary for its production.

Like electricity, the use of natural gas has grown faster than the use of energy in general. In 1950 only 6,753 trillion cubic feet (TCF) of natural gas were consumed. By 1973 this figure had jumped to 23,346.1 trillion cubic feet, an increase of 245.7 percent in only 23 years [American Gas Association]. As the result of this phenomenal growth, natural gas now provides about 30 percent of the energy used in the United States, as opposed to only 18 percent in 1950 [Federal Energy Administration, 1976]. The major stimuli to the expanded consumption of natural gas were the following: (1) the expansion of natural gas pipelines, allowing the development of a national market, (2) purchases of natural gas appliances and equipment, and (3) interstate price regulation by the Federal Power Commission (FPC).

Perhaps the greatest single factor in increasing the demand for natural gas has been price regulation by the Federal Power Commission. The Natural Gas Act of 1938 gave the FPC authority to regulate the price of natural gas flowing through interstate pipelines. The original intent of the Natural Gas Act was to prevent pipelines from practicing monopoly pricing, since any given region might be serviced by only one or two major pipelines. However, in 1954 the Phillips Petroleum Case extended the price regulating jurisdiction of the FPC to the well-head price of gas sold for use or resale in interstate commerce. The FPC controlled the price of natural gas below what the unregulated price would have been, with the result that natural gas was priced lower than alternative fuels on a BTU basis. Thus, energy users were encouraged to substitute natural gas for more expensive fuels, resulting in increased demand for natural gas.

Economic theory suggests that if a ceiling price is held below the equilibrium price of a good, over time, a chronic shortage will arise. Evidence that the FPC has indeed kept the price of natural gas below its equilibrium level is suggested by three facts. First, the prices of alternate (substitute) fuels are higher than the regulated price of natural gas, even though natural gas is a more desirable fuel from an environmental perspective. Second, in states where natural gas is produced, the price is not regulated and in those states the price is significantly higher than the regulated price. Finally, the annual amount of gas curtailment, which is an indication of natural gas shortages, has been steadily rising for a number of years [Federal Energy Administration, 1975].

The byproduct of FPC price regulation is market distortion. Price regulation encourages consumption while it discourages production. Furthermore, the current system of regulated price in some states and unregulated price in others is creating regional gas supply problems. The states in which gas is produced may offer a higher price to purchase new gas contracts than states with regulated price. This has predictably led to regional shortages of gas, since gas is bid away from the interstate market and tends to stay in the state where it is produced. The extent to which natural gas has been channeled out of the interstate market in the last several years is illustrated later in this report.

Trends in Supply

In recent years the domestic supply of energy has failed to keep pace with the demand for energy. The difference between domestic supply and demand has been increasingly supplemented by energy from foreign sources as is shown in Figure 3. The proportion of imported petroleum has risen from 19 percent in 1969 to 37 percent in 1975 [Federal Energy Administration, 1976]. In the years since the Arab embargo, the United States has become even more dependent on foreign petroleum. In 1973, the United States imported 33 percent of its petroleum. In January and February of 1977, the United States imported one-half of its oil consumption [Executive Office of the President]. This suggests increasing U.S. vulnerability to supply and price interruption from abroad.

There are many reasons why domestic supply has failed to keep up with domestic demand. Among them are the increasing cost of exploration, development and production, environmental concerns, government price regulations, declining production from existing oil and gas fields, and declining finds of new reserves. Production of oil and natural gas has significantly lagged behind demand for several years. Thus the primary focus of this section is with trends in the supply of petroleum and natural gas.

Petroleum

Domestic production of petroleum peaked at a level of 9.6 million barrels per day in 1970 and is now approximately 8.04 million barrels per day. A host of factors have contributed to the trend towards lower petroleum production. First, many of the older oil fields are beginning to run out of oil which is economically feasible to produce at the pre-

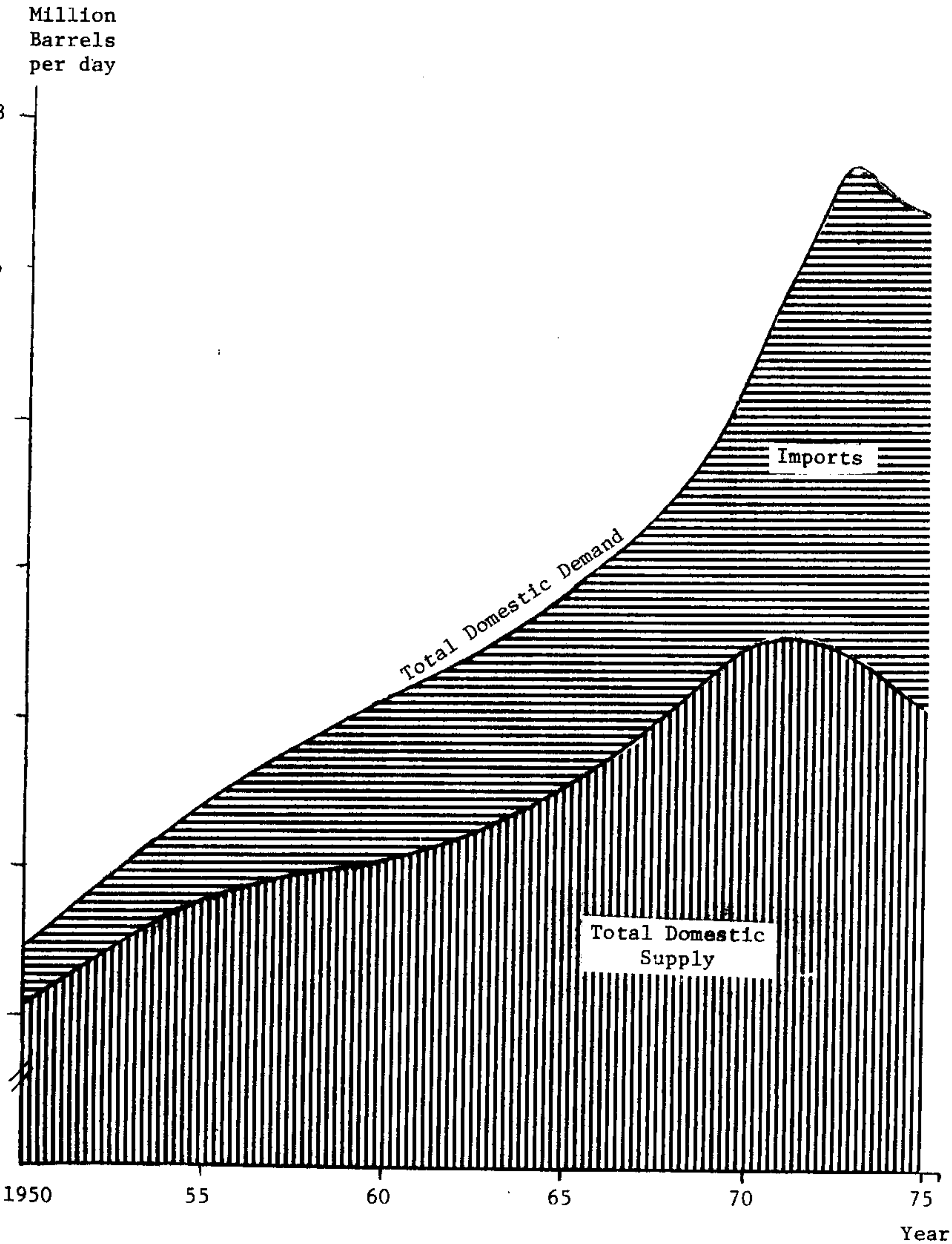

Figure 3. Source of energy used in the United States: 1950-75

Source: Federal Energy Administration, 1976 National Energy Outlook, United States Government Printing Office, Washington D.C., 1976.

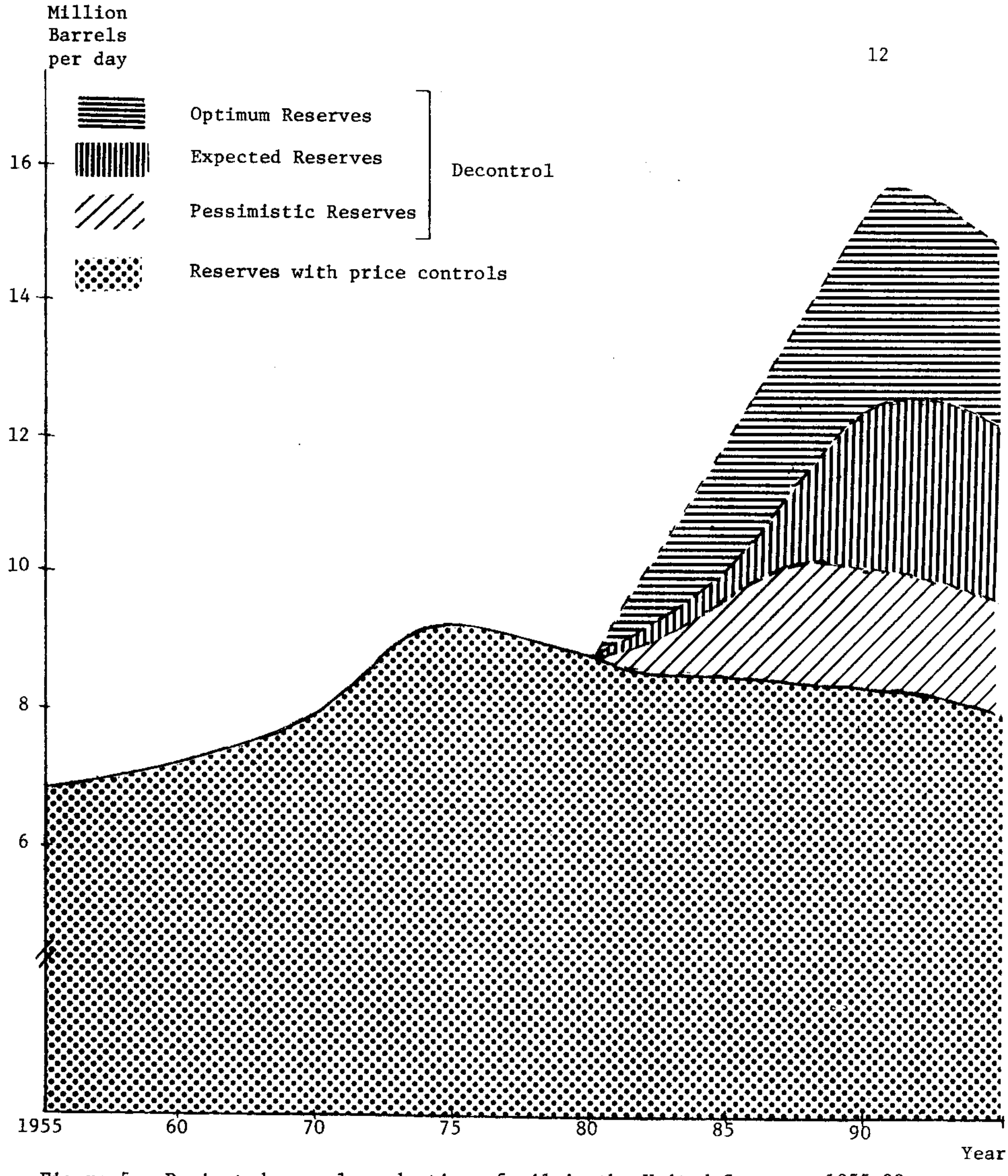

Figure 5. Projected annual production of oil in the United States: 1955-90.

Source: Federal Energy Administration, 1976 National Energy Outlook, United States Printing Office, Washington D.C., 1976.

vailing price level. Second, due to the high costs and risks associated with exploration, fewer exploratory wells are being drilled. Third, the new reserves that are discovered tend to lie at deeper levels and in smaller quantities than in the past. All of the above factors tend to raise the cost of production. Simultaneously government price regulation prevents revenues from rising in line with the cost of production and tends to discourage further exploration for oil and/or implementation of expensive secondary and tertiary recovery methods on existing fields.

The extent to which domestic petroleum production is affected by government price regulation is illustrated in Figure 4. The Federal Energy Administration projects that if the world price of oil falls to $8 per barrel or domestic price regulation continues over a long period of time, production of oil is unlikely to exceed its present levels. Unless the price of oil is allowed to rise in response to the supply and demand situation, it may be unprofitable to develop the more expensive fields such as Alaska and the Outer Continental Shelf. Even under the most pessimistic scenario presented by the FEA, price deregulation would allow production to increase until about 1985, after which it will begin to fall again. The Federal Government's best estimate for 1985 oil production is 12.3 million barrels per day [Federal Energy Administration, 1976].

Several things could happen to ameliorate the petroleum supply situation. As petroleum producers and consumers adjust to higher prices for oil, domestic production is expected to rise and domestic consumption is expected to grow at a slower rate. Also higher petroleum prices encourage the development and use of alternative energy sources. Enhanced conservation and efficiency of fuel could ease some of the pressure on

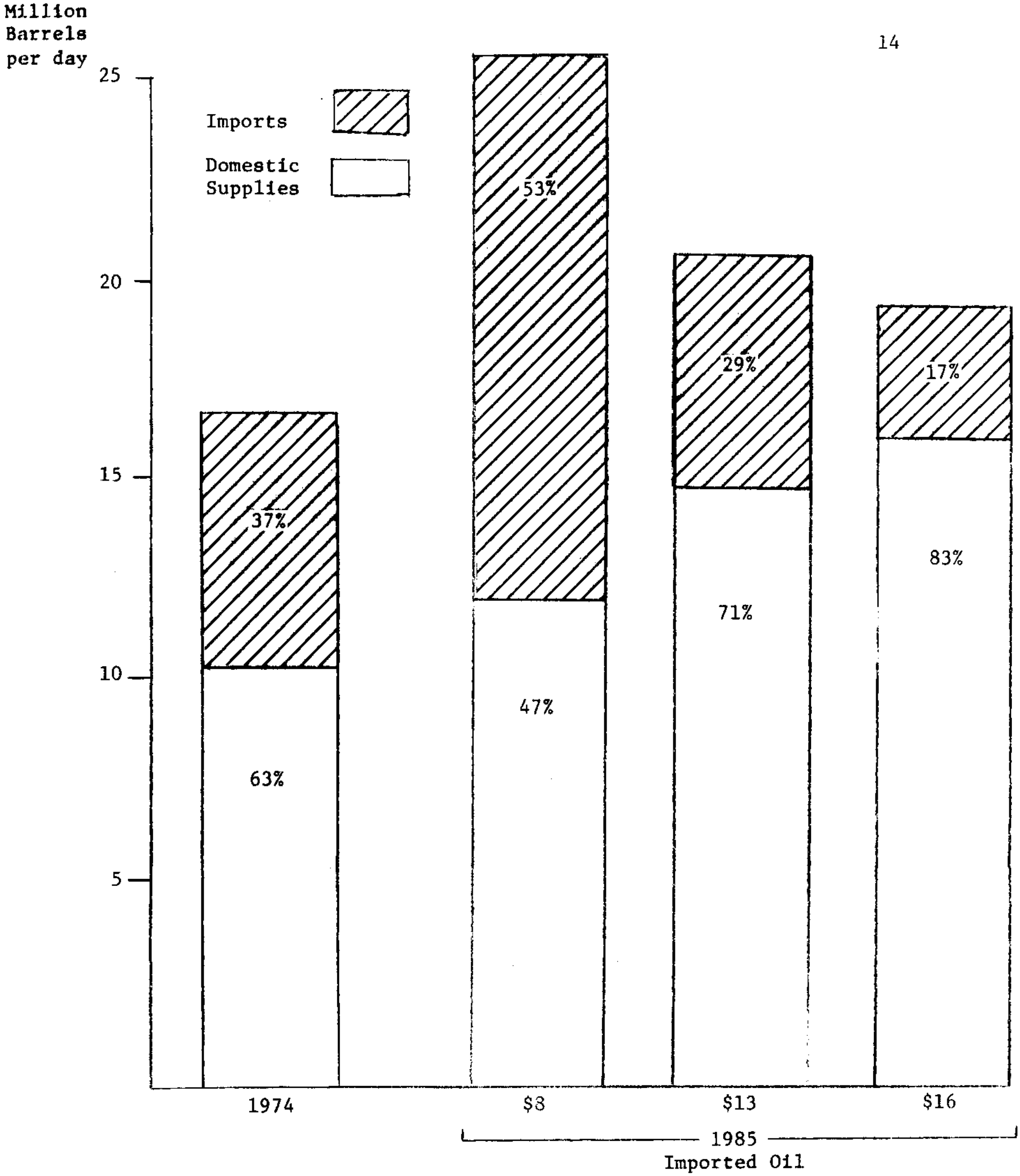

Figure 4. Projected consumption of petroleum in the United States at alternative prices for imported oil.

Source: Federal Energy Administration, 1976 National Energy Outlook, United States Government Printing Office, Washington D.C., 1976.

the oil supply. Furthermore, completion of the Trans-Alaska Pipeline will potentially boost domestic production by up to 2.5 to 3 million barrels per day. If the world price of oil continues at its high levels of recent years, the proportion of petroleum imported should stabilize in a few years. The Department of Interior projects a relatively stable petroleum import situation until the year 2000, with imports fluctuating between 35.3 percent and 41.9 percent of domestic consumption [Department of Interior]. The predication is contingent upon the development and utilization of new sources of energy to augment the domestic supply. Figure 5 indicates expected consumption and source of petroleum in 1985 assuming three alternative world oil prices.

Natural Gas

The supply of natural gas is rapidly becoming critical. Proved reserves of natural gas peaked in 1967 at 289.3 trillion cubic feet (TCF) and have since fallen continuously each year as shown in Table 1 and Figure 6. By 1973 proved reserves were only 218.3 TCF. While the reserves of natural gas fell, natural gas production, which is the amount of natural gas marketed (consumed), rose every year from 1946 to 1973.

Two measures of the natural gas supply, the R/P ratio and the F/P ratio, give an indication of the situation of natural gas supply. The R/P ratio, which represents the total amount of reserves divided by annual production (consumption), has fallen every year since 1946 except 1958 and 1962. The R/P ratio can also be interpreted as number of years that proved reserves could support a given level of production if no new reserves are added to proved reserves.

The F/P ratio represents the amount of annual production that is

Table 1. United States natural gas supply excluding Alaska: 1946–73[a]

Year	Production	Reserve Additions	Proved Reserves	R/P Ratio (4) ÷ (2)	F/P Ratio (3) ÷ (2)
		trillion cubic feet			
1946	4.9	17.6	159.7	32.5	3.6
1947	5.6	10.9	165.0	29.5	1.9
1948	6.0	13.8	172.9	28.9	2.3
1949	6.2	12.6	179.4	28.9	2.0
1950	6.9	12.0	184.6	26.9	1.7
1951	7.9	16.0	192.8	24.3	2.0
1952	8.6	14.3	198.6	23.1	1.7
1953	9.2	20.3	210.3	22.9	2.2
1954	9.4	9.6	210.6	22.5	1.0
1955	10.1	21.9	222.5	22.1	2.2
1956	10.9	24.7	236.5	21.8	2.3
1957	11.4	20.0	245.2	21.4	1.7
1958	11.4	18.9	252.8	22.1	1.7
1959	12.4	20.6	261.2	21.1	1.7
1960	13.0	13.8	262.2	20.1	1.1
1961	13.4	16.4	265.4	19.8	1.2
1962	13.6	18.8	270.6	19.9	1.4
1963	14.5	18.1	274.5	18.9	1.2
1964	15.3	20.1	279.4	18.2	1.3
1965	16.2	21.2	284.5	17.5	1.3
1966	17.5	19.2	286.4	16.4	1.1
1967	18.4	21.1	289.3	15.7	1.1
1968	19.3	12.0	282.1	14.6	0.6
1969	20.6	8.3	269.9	13.1	0.4
1970	21.8	11.1	259.6	11.9	0.5
1971	21.9	9.4	247.4	11.3	0.4
1972	22.4	9.4	234.6	10.5	0.4
1973	22.5	6.5	218.3	9.7	0.3

[a]Source: Federal Energy Administration, Project Independence Blueprint Final Task Force Report: Natural Gas (Under Direction of Federal Power Commission) United States Government Printing Office, Washington, D.C., November 1974. Data represents total U.S. natural gas supply prior to 1960. Includes gas in underground storage.

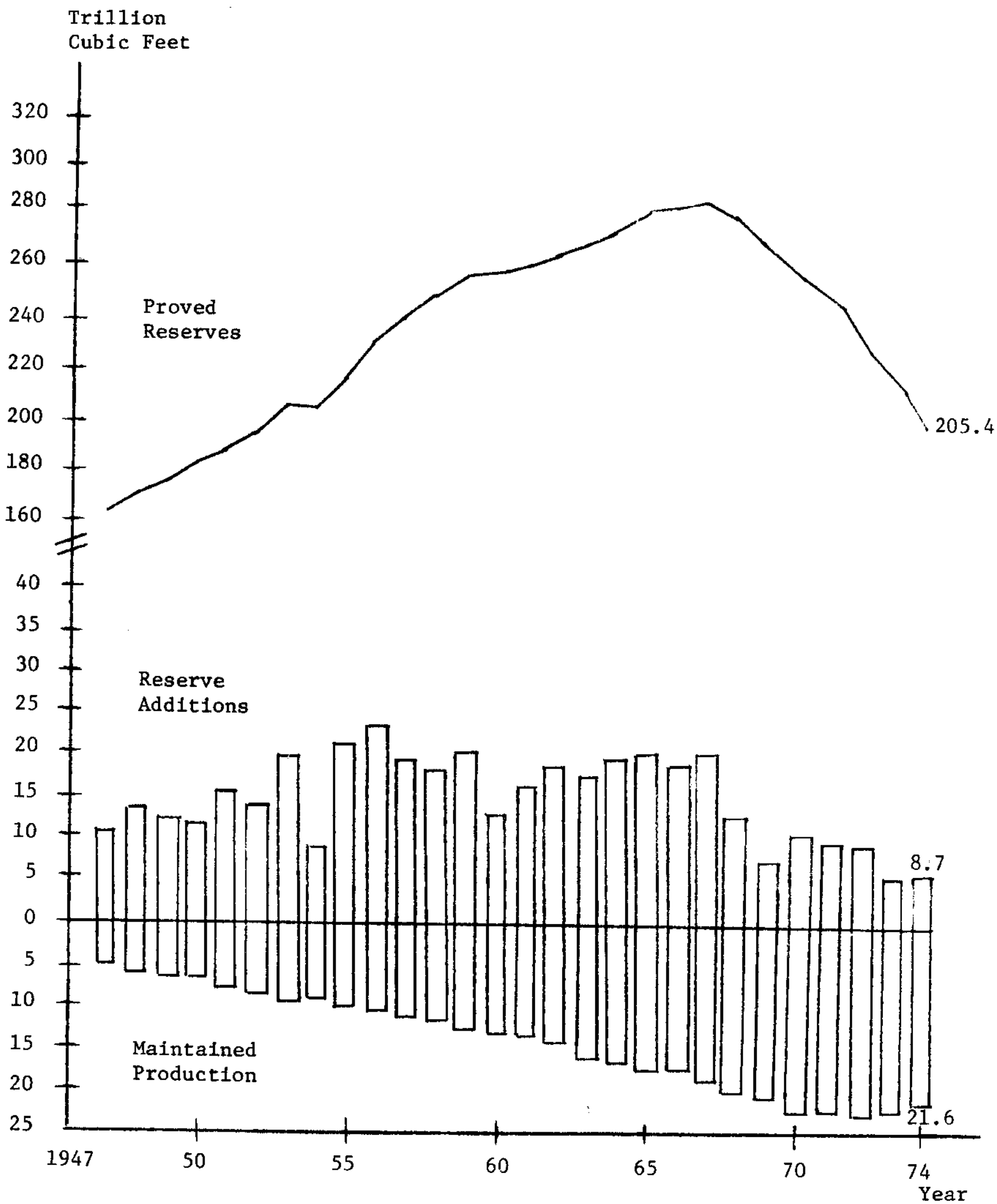

Figure 6. United States Natural gas reserves, excluding Alaska.

Source: Federal Energy Administration, <u>1976 National Energy Outlook</u>, United States Government Printing Office, Washington D.C., 1976.

replaced by new reserves. It too has fallen steadily since 1946. The implications of the R/P and F/P ratios are shown in the following example. In 1946 the R/P ratio was 32.5 and the F/P ratio was 3.6. This meant that at the 1946 level of production (consumption) the level of proved reserves could support 32.5 years of use with no new additions, but the amount of new reserves actually replaced 3.6 times the amount of natural gas that was taken out of reserves. Contrast that situation to the one in 1973. In 1973 the R/P ratio had fallen to 9.7 and the F/P ratio to 0.3. At the 1973 level of production (consumption) proved reserves, disregarding new reserve additions, were adequate to support 9.7 years production. Simultaneously new reserve additions only replaced three-tenths of the amount of natural gas withdrawn.

Federal Power Commission price regulation has distorted the supply and demand situation in the natural gas markets. Demand is stimulated by low gas prices while supply is discouraged. For example in 1974 and 1975 the amount of gas consumed in the United States fell, not due to a lack of demand, but because of falling natural gas production. The cost of finding and producing natural gas is increasing as new reserves are found at deeper levels and the cost of operating rises [Federal Energy Administration, 1974]. Faced with increasing costs and regulated prices, natural gas producers are producing less gas each year. Consequently, during the 1970's the supply of natural gas has not been large enough to satisfy demand. An indication of the price regulation induced shortage of natural gas is the growing level of natural gas curtailments each year [Federal Energy Administration, 1976].

The impact of price regulation on the future supply of natural gas is dramatically illustrated in Figure 7 which shows the expected supply

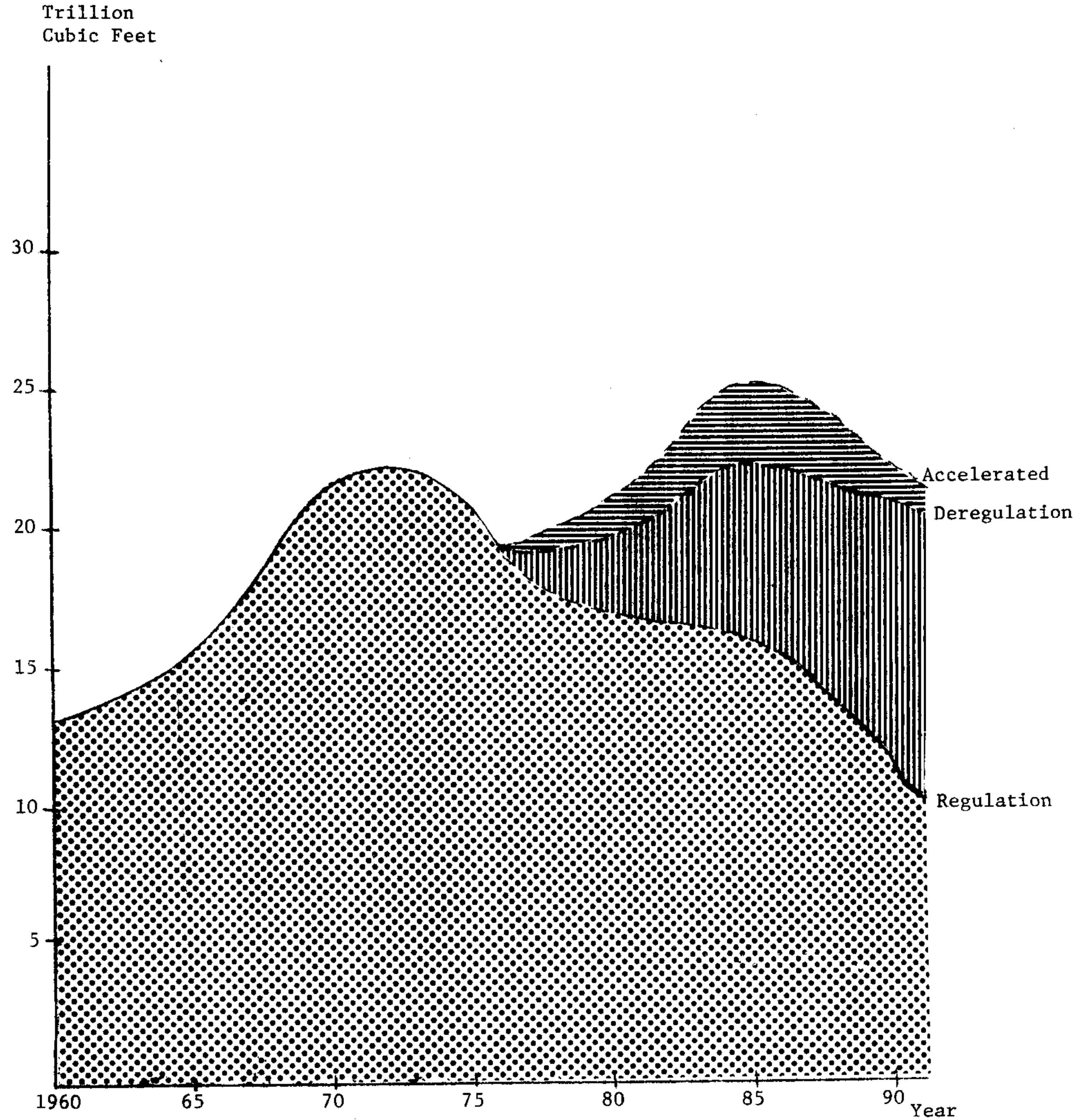

Figure 7. Projected natural gas production: regulated compared to unregulated price.

Source: Federal Energy Administration, 1976 National Energy Outlook, United States Government Printing Office, Washington D.C., 1976.

of natural gas under both price regulation and deregulation. If the price of natural gas continues to be regulated, production will continue to decline to about 17.9 TCF in 1985 and then decrease at an increasing rate until around 1990 when production becomes insignificant. If the price of gas is deregulated, production will continue to fall for a few years until new reserves are developed, and then will begin to increase to about 22.3 TCF in 1985 (2.2 TCF higher than in 1975). Furthermore, accelerated offshore drilling could allow production to reach 25.5 TCF by 1985. The difference between the projected level of production assuming price regulation and the level of products assuming the optimistic deregulation projection is 7.6 TCF (37.8 percent of 1975 production). The implication of the foregoing analysis is that the continued supply of natural gas in the United States is contingent upon swift action on the part of the Federal Power Commission or Congress to deregulate the price of new natural gas.

Trends in Price

Petroleum

The Arab Oil Embargo of 1973 signaled the end of the era of "cheap" energy in the United States. The initial shock of the embargo was upon the price of petroleum and petroleum products. The after shocks of the embargo were felt in the form of higher prices for all forms of energy. As the price of petroleum rose, energy users substituted other fuels for petroleum, putting pressure upon existing fuel stocks and forcing price increases. By the time the effects of the embargo dissipated, the energy market had reached a new equilibrium at a higher level of prices.

Given the heavy dependence of the world petroleum consumption on oil from OPEC nations and the price impact of their cartel actions, it is difficult to accurately predict future world petroleum prices. So far, OPEC nations have shown a great amount of discipline in maintaining world oil prices. There is little reason to believe that they will allow the price of petroleum to fluctuate very far in a downward direction. The OPEC strategy now seems to be to increase world petroleum prices gradually rather than in the large jumps of the past. Large price increases encourage importing nations to develop new energy sources and increase domestic exploration and production of petroleum. Furthermore, large price increases encourage consumers to use less petroleum and thereby lower dependence on OPEC oil. As a result, OPEC nations have an incentive not to raise prices too fast, in order to avoid erosion of their market power.

The future domestic price of petroleum is further obscurred by government price regulation. At the present time it is impossible to discern a clear direction in government pricing practices. It is clear, however, that the world oil price will have a great bearing on the domestic prices of petroleum and petroleum products for some time to come, since imports comprise such a large proportion of domestic energy consumption.

Natural Gas

A number of recent developments in the natural gas industry have forced the Federal Power Commission to take steps to raise the maximum allowable interstate price for natural gas. The current regulated interstate pricing system has caused serious maladjustments in the natural gas market. The price of gas produced in one state and sold in another (interstate) is subject to FPC regulation, but the price of gas produced and sold in the state of origin (intrastate) is not.

The market for gas consists of two distinct segments, an interstate market, which is regulated, and an intrastate market, which is competitive. Over a period of years, prices in the intrastate market have risen substantially above the maximum allowable price in the interstate market, with the result that new gas reserves are bid away from the interstate market. For example from January to June 1975, 99 percent of new gas contracts sold in the intrastate market were sold at prices above the regulated interstate [Federal Power Commission]. The average intrastate prices during that period was $1.25/MCF contrasted with the average regulated price of 52¢/MCF. From July to December 1975, 98.8 percent of new intrastate contracts sold at prices above the interstate rate. On average, the price of gas sold on the intrastate market was approximately three times higher than the interstate price.

Gas producers sell new contracts of natural gas on the intrastate market first, then market the residual on the interstate market at a lower price. In effect, new contracts are bid away from the interstate market by consumers in the state of origin. Between 1964 and 1969, 67 percent of net reserve additions were sold interstate and only 33 percent were sold intrastate. By 1970 to 1973 a mere 8 percent of net reserve additions were marketed interstate, while 92 percent were marketed intrastate, as shown in Figure 8. The situation has forced firms and households in many regions of the United States to face severe natural gas shortages, while other regions have an abundant gas supply.

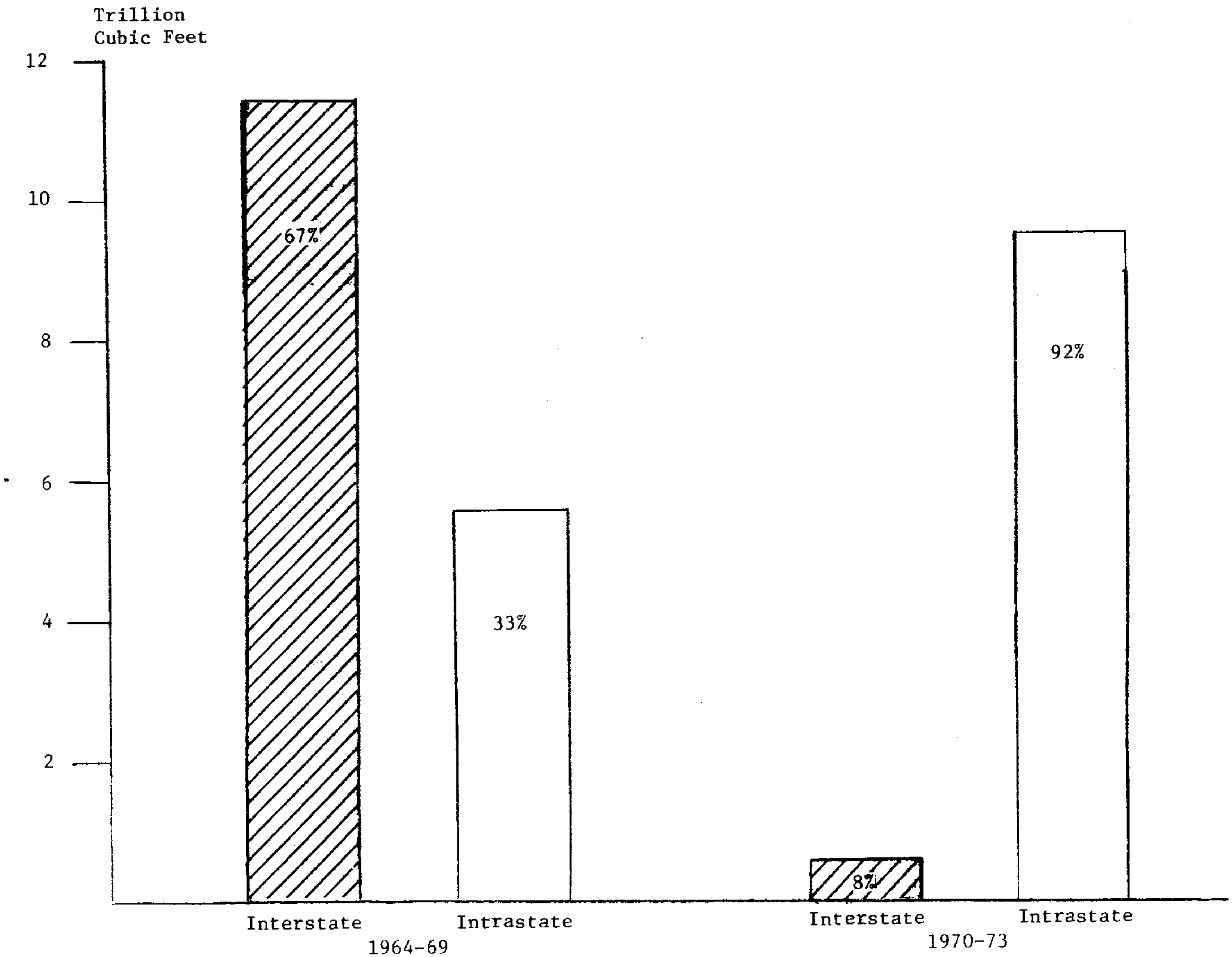

Figure 8. Average annual net reserve additions to interstate and intrastate pipelines: 1964-69 and 1970-73.

Source: Federal Energy Administration, "The Natural Gas Shortage: A Preliminary Report," August 1975.

The Federal Power Commission has granted many companies emergency permission to offer prices above the interstate price in order to assure a stable gas supply. The FPC is also in the process of raising the maximum allowable interstate price of gas, so that interstate purchasers can become competitive with intrastate purchasers. The Governor's Energy Advisory Council of Texas summarizes the rate changes as follows:

> "The announced price ceilings include \$1.42 per thousand cubic feet for "new" gas. The rate is applicable for (1) sales of natural gas made from wells commenced on or after January 1, 1975, and (2) sales made pursuant to contracts executed on or after January 1, 1975, for the sale of natural gas in interstate commerce where such gas has not previously been sold in interstate commerce. The \$1.42 rate will be adjusted at the rate of 4¢ per year, 1¢ quarterly, beginning October 27, 1976.
>
> Natural gas brought into production in the two year period from January 1, 1973 through December 21, 1974 may be sold at \$1.01 per MCF, while "old" (flowing) gas will remain at the 29.5¢ per MCF rate. For renegotiating contracts the maximum rate allowed will be 53¢ for the "old" (flowing) gas contracted prior to January 1, 1973. The 53¢ rate will continue to be increased by 1¢ per year effective July 1, 1976, as under previous rulings." [Governor's Energy Advisory Council]

There has been a great deal of controversy over the proposed rate increases. Consumer's groups have protested that the FPC has based its decision too heavily on information provided by the natural gas industry and too little on projected cost estimates from the consumer's point of view. The Federal Power Commission initially estimated the annual cost of the price increase to consumers at \$1.5 billion. This estimate was later revised upward to \$2 billion. In light of the new cost estimates, the Federal Power Commission has decided to temporarily rescend part of the rate increase. The current status of the proposed rate hikes is that the original rate hike will be put into effect, but part of the price increase is subject to refund if the cost to consumers is higher than anticipated.

The cost of using interstate natural gas is going to increase rapidly as new and renegotiated gas contracts are sold at the new rates. The price increases will have very little effect on the price of gas in gas producing states such as Texas and Louisiana which already pay prices higher than the new interstate regulated rates. The interstate market will be significantly affected by the higher price of natural gas but will be better able to compete with gas producing states for reserves. The higher prices should also encourage exploration and development of more expensive fields but will have a negligible effect on secondary and tertiary recovery of abandoned wells since the initial recovery rate for gas wells is about 90 percent.

Although the cost of using natural gas is rising, it still remains less expensive on a BTU basis to use natural gas than to switch to alternate fuels. Higher prices of natural gas and fuel oil will lead to higher electricity costs since many plants use gas and fuel oil as boiler fuels. Thus, higher prices for all forms of energy appear to be the trend for the foreseeable future.

The Trends in Perspective

The United States is clearly going through an adjustment period in terms of energy usage. The adjustment process is likely to be long and painful. As supplies of oil and natural gas grow scarce relative to the demand for them, pressure will be put on prices. Government intervention to hold prices down will only cause shortages. Thus, the period ahead will most likely be one of higher prices for all forms of energy.

Higher prices for oil and gas will eventually lead to substitution of other more abundant energy sources. The transition from oil and gas to other power sources will not be frictionless. For example, if coal is substituted on a large scale for oil and gas there is likely to be significant environmental implications. Furthermore, production of many of the new energy resources will entail problems with respect to water usage.

Water usage for energy production is large relative to most industrial uses. For example, oil shale production requires 145.4 gallons of water per barrel of oil. Similarly, coal liquification requires between 175 and 1,134 gallons per barrel. Thus, production of oil shale requires between 1,012 percent to 6,555 percent more water per barrel [Federal Energy Administration, 1975].

Development of new energy resources will place a heavy burden on existing water resources, particularly in arid and semi-arid regions where most water supplies are already committed to other uses, primarily agricultural. The energy industry will be in direct competition with agriculture for the available water supply in many regions. There are some indications that the energy industry may have the competitive edge in bidding for water, in that the value of water in energy production is substantially higher than its value in irrigation [Beattie, 1976]. Consequently, definition of water rights, particularly in western states will be of critical importance to irrigated agriculture.

Implication for Irrigated Agriculture

The previous sections of this paper indicate some broad prospectives and forces that affect the United States energy situation. Energy is a complex issue which is difficult to define, describe or explain due to the multitude of factors that must be considered. However, with this rather brief description of several of the factors, some insight relative to the future is clear. The purpose of this paper is now to relate the changing energy situation to its expected impact on irrigation. This will be accomplished by reviewing energy use in irrigation, associated costs, costs of converting energy sources, the value of water used in irrigation and the expected effect on acres irrigated.

Energy Use for Irrigation

Sloggett and Gavett indicate that in 1974, an estimated 453 trillion BTU's were used for pumping irrigation water and for the additional tillage, harvest, fertilizer and pesticides required on irrigated land relative to dryland production. This amounts to about 65 gallons per acre of oil equivalent for irrigated land above dryland requirements.

This suggests that energy used for production of irrigated crops is from 50 percent to three times more than is required for comparable dryland production (Fox). Dvoskin, Nicol and Heady estimate that 25 percent of all the direct energy used in crop and livestock production is for irrigation. This amounts to one percent of the gasoline, 13 percent of the LPG, under three percent of diesel, and nearly all the natural gas and electricity used in crop and livestock production.

Irrigation is quite energy-intensive. Studies show that irrigation is very important in the 17 Western States and Louisiana and Florida (Dvoskin, Nicol and Heady). Irrigated cropland in 1974 for the 17 Western States accounted for more than 88 percent of the nation's irrigated cropland.

Slogget and Gavett estimate that in 1974 there were 35 million acres of cropland and 15 million acres of hay and pasture irrigated in the United States. The Sloggett and Gavett information was separated out for the Great Plains Region by a Task Force of the Great Plains Agricultural Council. Tables 2 and 3 present the Task Force information on acres irrigated with each energy source and energy required per acre foot of water by state. Texas and Nebraska have the largest number of irrigated acres at 8,618 and 5,338, respectively. In the Great Plains the principal source of energy for pumping is natural gas, followed by electricity.

Energy used to pump an acre foot of water varies considerably throughout the Great Plains, and in fact, within states. New Mexico has the largest energy requirements for pumping, followed closely by Oklahoma and Wyoming. In the Great Plains, Nebraska and Colorado have the smallest energy requirements to pump an acre foot of water.

Value of Irrigation Water

Irrigation is important to the Western States due to the lack of rainfall. In many areas, crop production is possible only with irrigation. Estimates of the impact of increasing energy prices on irrigation is directly related to the value of the groundwater used in crop production; i.e.,

Table 2. Acres irrigated by power source in the Great Plains; 1974[a]

State	Irrigated acres	Energy Source				
		Electricity	Diesel	Gasoline	Natural gas	LPG
	1,000					
Colorado	3140	1100	100	20	330	100
Kansas	2360	169	138	22	1792	183
Montana	2231	271	37	14	0	3
Nebraska	5338	1308	1360	118	637	1331
New Mexico	1062	204	47	31	484	54
North Dakota	78	42	9	3	0	1
Oklahoma	738	102	49	20	435	113
South Dakota	202	52	36	8	0	37
Texas	8618	1904	102	88	6307	395
Wyoming	1798	191	18	3	7	6
Great Plains	25,565	5343	1896	327	9992	2223
United States	51,719	15,621	3934	1071	10,635	3338

[a]Source: Slogget and Gavett as presented in Task Force of Great Plains Agricultural Council.

Table 3. Energy use per acre foot of groundwater pumped in the Great Plains; 1974[a]

State	Energy Source				
	Electricity (kwh)	Diesel (gal.)	Gasoline (gal.)	Natural gas (mcf)	LPG (gal.)
Colorado	413	34	43	5	53
Kansas	560	46	58	7	72
Montana	641	53	66	8	83
Nebraska	410	34	42	5	53
New Mexico	977	80	101	13	126
North Dakota	696	57	72	--	90
Oklahoma	796	66	82	10	102
South Dakota	613	50	63	--	79
Texas	575	47	59	7	74
Wyoming	739	61	76	10	95
United States	1002	31	30	7	44

[a]Source: Sloggett and Gavett as presented in Task Force of Great Plains Agricultural Council.

farmers' ability to pay for the energy. Thus, some estimates of the value of groundwater are useful to this discussion. There are numerous estimates of the value of irrigation water with the value a function of crop and geographic location. In the National Water Commission's final report, a value for irrigation water at the farm gate of between \$15 and \$40 was given. This means costs of pumping must be deleted to obtain farmer returns to water. These estimates of the value of irrigation water are supported by other studies such as Shumway; Grubb; Beattie; and Lacewell and Grubb.

However, most of the studies are based on data for the 1960's or early 1970's. Dramatic price shifts for both agricultural products and inputs have a direct affect on the value of irrigation water. A 1975 study by Condra, Lacewell, Sprott and Adams indicate the value of irrigation water on the Texas High Plains to be about \$37 per acre foot using a 1971-74 average crop price. When the high crop price over the 1971-74 period is used, the value per acre foot of irrigation water increases to about \$114.[1/] These estimates represent value of water at the farm gate; hence, to be applicable to groundwater, costs of pumping must be deleted.

A range of \$37 to \$114 for the value per acre foot of irrigation water is quite wide. A study by Beattie (1976) provides additional estimates which somewhat narrow the range and indicate the effect of crop and location. These estimates are based on 1969 Census data inflated to

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[1/] A serious limitation to using the high price for 1971-74 for each commodity is they are not likely to all be high at the same time nor or they likely to remain high. This suggests the \$114 per acre foot value for irrigation water is an overestimate for any kind of planning purposes.

1976 prices. The study areas considered were the Texas High Plains and South Texas. The value of irrigation water used on the major crops in each area was weighted by percent of all planted cropland in the region typically allocated to each crop. This gives an estimate of the value of irrigation water across all crops. For the Texas High Plains, the 1976 Beattie estimate for value of irrigation water is from \$40 to \$65 per acre foot compared to \$32 to \$45 per acre foot for South Texas.

A comparison of the different estimates of irrigation water is presented in Table 4. Comparing these irrigation values to other water users, Beattie (1976) further reported value per acre foot of water of from \$116 up in urban residential uses and \$603 in secondary oil recovery. There are of course numerous other uses of water such as recreation, industrial, environmental enhancement, bays and estuaries, etc. Evidence suggests that the value of water used in agriculture is low compared to other users. This means agriculture is not in a position to competitively purchase water from other users and in fact, just the opposite applies. This implies that in areas of limited water, we can expect more pressure on current water supplies being used in agriculture for expanding urban areas, energy development, etc.

A last point relative to the value of water used in agriculture is presented here. As one would expect, value of irrigation water is very sensitive to the price of crops produced. To illustrate, we return to the 1976 study by Beattie. Table 5 presents several crops in the Texas High Plains and Lower Rio Grande Valley indicating the value per acre foot of irrigation water assuming different crop prices.

Table 4. Value per acre foot of irrigation water[a]

Source	Irrigation Water Value ($/ac.ft.)		
	Low	High	Average
Nat. Water Commission	15	40	20
Grubb--Texas High Plains	26	32	NA
Lacewell & Grubb--High Plains	20	38	NA
Beattie (1971)--High Plains	20	33	24
Condra, Lacewell, Sprott, Adams--Texas	37	114	NA
Beattie (1976)--High Plains	40	65	53
Beattie (1976)--South Texas	32	45	44

[a]Value at the farm gate. To estimate value of groundwater, costs of pumping must be deleted.

For the High Plains, the range given shows a positive value for irrigation water, but the effect of crop price on this value is often \$70 or more per acre foot. Alternatively, in South Texas there are several crops that show a negative return to water at low prices indicating that they are risky investments, but ones with which there is often an opportunity to make very large profits as shown by the high value of water when there is a high crop price; i.e., from negative \$266 to \$212 for onions.

This provides some estimates of the value of irrigation water or benefit side of the equation. With this information regarding agriculture's ability to pay for irrigation water, completion of the analysis requires a look at the costs associated with irrigation.

Cost of Pumping Groundwater

Since the predominant source of irrigation water in the Great Plains is groundwater, the emphasis in this paper will be on costs of pumping from an aquifer. In the case of the Ogallala aquifer, these costs comprise the bulk of the variable aquisition and application costs of irrigation water.

Perhaps it is appropriate to begin with some examples. Natural gas produced and sold within Texas is not subject to interstate Federal Power Commission price regulations. Therefore, a competitive market situation exists in Texas. With stress on the supply side, market forces have resulted in natural gas price increases in Texas. In turn, natural gas is generally available within the State, hence, the possibility of curtailment is quite small.

Table 5. Value per acre foot for irrigation water for selected crops and different crop prices: Texas High Plains and South Texas[a]

Item	Yield (acre)	Crop Price (dollars)	Value of Irrigation (dollars/acre foot)
<u>Texas High Plains</u>			
Cotton	500 lbs.	.40	47
	500 lbs.	.60	121
Sorghum	60 cwt	3.50	35
	60 cwt	4.50	68
Corn	120 bu	2.00	33
	120 bu	3.00	109
Wheat	40 bu	2.00	36
	40 bu	3.00	101
Soys	30 bu	4.00	11
	30 bu	6.00	59
<u>South Texas</u>			
Cotton	550 lbs.	.45	0
	550 lbs.	.65	84
Sorghum	40 cwt	3.50	1
	40 cwt	4.50	47
Carrots	300 bags	3.50	-6
	300 bags	4.50	163
Onions	400 bags	2.00	-266
	400 bags	4.00	212
Cantaloupes	300 crates	4.00	107
	300 crates	6.00	446

[a]Source: Beattie (1976)

The situation in the Trans-Pecos region of Texas provides a dramatic example of the impact of rising natural gas price on irrigated agriculture. Prices have increased from about $0.50 mcf to $1.85 and higher. For 300 acres of cotton, this price rise alone increases pumping costs from about $4,800 to $22,000. For the Texas High Plains, natural gas price increases from $0.80 mcf to $1.30 mcf have resulted in an increase in irrigation cost for 300 acres of sorghum of about $1,900; i.e., from $3,100 to $5,000 (Texas Water Resources Institute). This cost would rise to $7,800 if natural gas prices increased to $2.00 mcf in the area.

We have already discussed the energy situation and what might be expected. Quoting material in an article by Sorenson, "oil and gas prices are estimated to double, triple or increase five times by the end of the century. One expert even predicts natural gas prices 7 to 10 times greater by 1985." With an increasing price for energy, information on pumping costs under different conditions is needed.

Engine Pumping Costs

Table 6 indicates estimated engine pumping costs per acre foot of water for different energy sources, prices and well characteristics.[2/] Naturally, with increased lift, fewer annual hours of use, and higher fuel prices, there is a higher engine cost to pump an acre foot of water.

[2/] These data are results from a research project at Texas A&M involving Wayne LePori, Dick Tremble and Ron Lacewell. The project was funded by Detroit Diesel with the objective of developing a computer program for estimating engine costs of pumping water under selected conditions and prices. A report will be forthcoming from this endeavor.

Table 6. Engine costs associated with pumping an acre foot of irrigation water under specified situations[a]

Well Yield (gpm)	Well Depth (feet)	Annual Hours Pumping	Energy price per unit											
			Natural gas (mcf)						Diesel (gal.)			Electricity (kwh)		
			Auto			Industrial								
			1.25	1.75	2.25	1.25	1.75	2.25	.35	.45	.55	.03	.04	.05
350	100	1000	9.10	10.88	12.89	---	---	---	14.09	16.17	18.25	10.25	13.05	15.85
350	100	3000	8.63	10.41	12.42	---	---	---	11.70	13.78	15.86	9.51	12.31	15.11
800	350	1000	18.77	24.16	30.25	18.58	23.58	29.22	31.29	37.60	43.91	28.66	37.14	45.63
800	350	3000	18.47	23.86	29.95	17.68	22.68	28.31	28.30	34.61	40.92	27.25	35.74	44.22
1200	500	1000	---	---	---	29.90	36.91	44.81	43.22	52.07	60.92	39.90	51.80	63.70
1200	500	3000	---	---	---	27.09	34.10	42.00	39.16	48.01	56.86	38.03	49.92	61.82

[a]Total annual variable and fixed costs per well are available from the authors. These results are preliminary and subject to adjustments. These costs are based on furrow irrigation with a pump efficiency of 50% and power unit efficiency of 22.5% for natural gas automobile, 24% for natural gas industrial, 31.5% for diesel industrial and 90% for electricity.

A very general review of the table suggests that natural gas at a price of $2.25/mcf is still very competitive with $0.35/gal. diesel and $0.03/kwh electricity. The table further indicates that at roughly $2.25 natural gas, $0.35 diesel and $0.03 electricity, the cost per acre foot of water pumped increases from about $13, at 100 feet of lift, to approximately $40 at 500 feet of lift. These values are, of course, a function of gallons pumped per minute and annual hours of use.

Considering pumping costs with different fuels, a breakeven price between natural gas and diesel and electricity was estimated for Arizona (Willett, Hathorn, Robertson and Pate). This Arizona study generally supports the results generated in Texas. For example, at a natural gas price of about $1.00/mcf, the breakeven price for electricity is about $0.012/kwh and for diesel, near $0.13/gal. assuming the price of natural gas is about $2.00/mcf, a comparable electricity price is $0.021/kwh and price of diesel at $0.28/gal. This suggests some dramatic price increases in natural gas will be required to make other fuels really competitive.

Relating engine pumping costs back to the value per acre foot of water used for irrigation, it is evident that increases in the cost of energy, coupled with declining groundwater, are rapidly placing engine pumping costs near, and even above, the value of the water used for irrigation. This carries a very serious implication for irrigation, where the water is deep and costs of energy rising. The intent of these data is not to alarm the reader but simply point out that much of the profit in irrigated farming has been eroded. This implication cannot be taken lightly since the engine pumping costs presented do not even include a charge for the pump or drilling the well. Clearly the challenge is

Table 7. Engine costs per acre foot of water pumped with selected conversion from natural gas[a]

Item	Costs per acre foot of water: Original, Nat. gas price (mcf) $0.70	Original, Nat. gas price (mcf) $1.09	Converted, Nat. gas price (mcf) $0.70	Converted, Nat. gas price (mcf) $1.09	Converted, Alternate fuel only
	- - - - - - - - - -	- - dollars - -	- - - - - - - -		
Under 400 cu. in. (gasoline)	8.47	11.41	22.15[b]	23.62[b]	--
<u>Over 400 cu. in.</u>					
automobile class (gasoline)	11.62	15.98	27.18[b]	29.30[b]	46.00
industrial class (elec.)	9.18	11.83	--	--	27.29
industrial class (diesel)	9.18	11.83	--	--	26.21

[a]Source: Osborn. Prices of fuel are $0.43/gallon for gasoline, $0.343/gallon for diesel, $0.033/kwh for electricity and $0.70 and $1.09 for natural gas/mcf.

[b]Assumes 50% gasoline and 50% natural gas

before us.

Engine Conversion to Alternative Energy Source

The results of the previous section were estimated based on a given engine with no engine conversion costs assumed. However, if a farm operator decides to shift from one energy source to another, some additional costs will be incurred. For example, Sorenson, citing a Kansas study, points out that the cost of converting natural gas powered wells to electric power would be about $12,000 per well. Conversion to diesel units would involve even higher costs.

Osborn, at Texas Tech University, developed some estimates of engine conversion costs associated with switching to alternative fuels. The estimates presented in Table 7 apply in general to the Texas High Plains but provide relative values useful for other irrigated regions. In his analysis, the following fuel prices were used: gasoline, $0.43/gallon; diesel, $0.343/gallon; natural gas, $0.70 and $1.09/mcf; and electricity, $0.033/kwh. Basically the data indicate that with a natural gas price rise from $0.70 to $1.09/mcf it is not economical to convert any of the engines to gasoline, diesel or electricity. For example, in the industrial engine class, to convert to electricity, engine pumping costs are an estimated $27.29 per acre foot and $26.21 for a diesel conversion compared to $11.83 when natural gas is $1.09/mcf. This indicates that some rather large natural gas price increases relative to the prices of these other energy sources will be required before conversions from natural gas to other power sources is economically sound. However, one factor that could drastically change these conclusions would be curtailment of natural gas flow to irrigation engines.

Willett, et. al., in an Arizona study estimated that based on three case study wells, conversion from natural gas to diesel or electricity would increase pumping costs between \$11.50 and \$15 per acre foot. This analysis was based on an assumed natural gas price of \$1.02/mcf, diesel price of \$0.387/gal. and electricity price of \$0.0275/kwh.

Effect of Energy Costs on Irrigation

A simple comparison of the value per acre foot of irrigation water and engine pumping costs per acre foot suggests there is not much slack in the system. Particularly when one remembers that costs associated with drilling a well, installing the pump and maintenance of the pump have not been accounted for.

There are several studies directed at estimating the effect of rising energy prices on irrigation. Sorenson, reporting on a U.S. Department of Agriculture study by Sloggett and Gavett, quotes them as follows:

> "When facing increasing costs of energy some farmers in areas of declining groundwater supply will have to make some difficult decisions about irrigation."

The researchers continued,

> "Even if water doesn't get scarce, with natural gas now at \$1.00 mfc and a predicted 5 or 10-fold increase, it is possible that some farmers will not be able to economically pump irrigation water with natural gas in the next 10 or 20 years" (Sorenson, p. 31-32).

Another study comes to a similar conclusion and we quote,

> "...marginal pumping operations may find the economic dividing line shifting against them. Heavy investments in distribution systems may become economically unsound operations. Those areas heavily dependent upon natural gas will likely be the first squeezed by limited supply and increased costs" (Task Force Report, p. 25).

Extending beyond the general statements, a few specific cases are used to emphasize the point.

Texas Trans-Pecos

The Texas Trans-Pecos region has experienced one of the most dramatic price increases for natural gas in the country. The impact of this on irrigation has been estimated by Condra and is presented in several reports (Condra and Lacewell; Lacewell, Condra and Fish; Lacewell 1966; and LePori and Lacewell). The impact of the natural gas price increase from $0.40 to $1.85/mcf has resulted in production costs increasing from $30 to $90 per acre. This amounts to a 450 percent increase in price of natural gal and translates into a 60 percent increase in the cost of irrigation. Relating these higher production costs to individual crops, a product price for each crop that would be required to exactly cover all costs of production was estimated. This is defined as the breakeven product price. The values in Table 8 show that all crop enterprises are returning less than the costs of production.

In terms of water pumped, producers using $0.40/mcf natural gas incurred a cost of $2.12 per acre inch of water pumped compared to $3.40 per acre inch of water pumped at $1.85/mcf for natural gas. Based on this disparity between current crop prices and prices required to breakeven, it must be concluded that the majority of the land in the Trans-Pecos region will not be held in crop production activities indefinitely under the current input and output price situation.

The majority of irrigated producers in this area, if current conditions continue, will be forced out of production by the laws of economics. Their land will revert to range land with less than native productivity

Table 8. Increase in costs of production associated with natural gas price increase and effect on economic viability of crops irrigated: Texas Trans Pecos[a]

Crop	Unit	Water applied (acre inches)	Increased Production cost per acre dollars	Crop Prices	
				Breakeven	Recent[b] Market
Alfalfa	ton	72	92.16	102.39	55.00
Barley	bu	38	48.64	3.87	2.75
Cantaloupe	crate	24	30.72	7.04	6.50
Cotton--Pima	lb. lint	44	56.32	1.25	.70
Cotton--Upland	lb. lint	44	56.32	.77	.50
Sorghum--Forage	ton	36	46.08	14.29	12.00
Sorghum--Grain	cwt	28	35.84	6.99	4.50
Wheat	bu	24	30.72	4.52	4.00

[a]Source: Condra and Lacewell. Based on a natural gas price increase of from $0.40 to $1.85/mcf.

[b]Prices in late 1975 and early 1976.

and the income from most of the irrigated production will be lost to the region.

If land reverts from irrigation to extensive livestock operations, there are important regional economic implications. Producers buy inputs such as fertilizer and fuel from local suppliers and market products to local processors such as cotton gins, grain elevators, etc. This means the adjustments from irrigated crop production to livestock operations will affect many phases of the local economy.

Texas High Plains

Another Texas region where research is available on expected effect of increasing energy costs relative to irrigated agriculture is the High Plains. A linear programming model was used for the analysis. Details of the model and several of its applications to particular problems is presented in Lacewell (1976); Lacewell, Condra and Fish; Lepori and Lacewell; Lacewell and Condra; and Condra, Lacewell, Sprott and Adams.

This analysis is based on model results evolving from parametrically increasing the price of natural gas. Two sets of crop prices were used. They included a 1971-74 (48 month) unweighted average for the High Plains and crop prices that prevailed in early 1976. This provides two sets of prices which provide an indication of model sensitivity.

The 1971-74 average prices used were corn at \$1.95 per bu., cotton at \$0.31 per lb., grain sorghum at \$3.10 per cwt, soybeans at \$4.25 per bu., and wheat at \$2.60 per bu. The early 1976 projections were corn at \$2.70 per bu., cotton at \$0.42 per lb., grain sorghum at \$4.25 per cwt, soybeans at \$4.50 per bu., and wheat at \$3.75 per bu. Only single-level irrigated enterprises were considered for corn and soybeans, however, alternatives for the other three crops include dryland production and different levels of irrigation. It has been assumed that all irrigated enterprises are under a furrow irrigation system and typical management applies to all crop enterprises.

Regional Implications

Results from the analysis using a $15 per acre land charge and no charge against the water resource beyond non-fuel pumping costs indicates expected regional agricultural production adjustments due to natural gas price increases. Table 9 shows producer returns to water, management and risk, irrigated acres, and crop output for the 1971-74 average crop prices. These crop prices are relatively low compared to current prices, hence they represent a lower bound.

As the natural gas price rises from $0.80 to $2.12/mcf, net returns to producers decline $39.5 million compared to those at the $0.80 natural gas price. In addition, irrigated acres decline 15 percent with cotton going completely out of production.

Shifts continue to occur up to a natural gas price of $4.67/mcf where all production is dryland and net returns are $32.4 million. This is compared to net returns of $99 million at an $0.80 natural gas price.

This analysis indicates that at a natural gas price of about $2.50/mcf important shifts begin occurring rapidly in irrigated acreage, producer net returns, and agricultural output, given the 1971-74 average crop prices.

To consider the effect of crop price, a set of prices were also used that represent late 1975 and early 1976 levels. The results using the 1976

Table 9. Expected Crop Output, Irrigated Acreage and Producer Net Returns for Alternative Natural Gas Prices, Texas High Plains[a]

Item	Unit	Price of Natural Gas per 1000 cubic feet								
		0.00	0.80	2.12	2.47	2.80	3.00	3.37	3.82	4.67
		- - - - - - - - 1,000,000 - - - - - - - -								
Net Returns[b]	dol.	129.9	99.0	59.5	49.0	40.7	38.0	35.8	33.3	32.4
Irrigated Acres[c]	ac.	2.6	2.6	2.6	2.2	1.3	0.5	0.5	0.3	0.0
Crop Output										
Corn	bu	180.8	148.9	115.2	115.2	23.3	23.3	23.3	0.0	0.0
Cotton	lb.	203.5	203.5	203.5	0.0	0.0	0.0	0.0	0.0	0.0
Grain Sorghum	cwt	29.3	29.3	40.0	40.0	40.0	12.0	12.0	12.0	15.3
Soybeans	bu	0.9	11.1	11.1	11.1	11.1	11.1	8.7	8.7	0.0
Wheat	bu	12.1	12.1	16.7	16.7	29.3	29.3	30.3	30.3	30.3

[a]Source: Lacewell, Condra and Fish.
Based on a per acre \$15 charge for land and no charge for water on acres irrigated. Crop prices are 1971-74 average and are cotton \$0.31/lb., cottonseed \$100/ton, wheat \$2.60/bu, corn \$1.95/bu, soybeans \$4.27/bu, and grain sorghum \$3.10/cwt.

[b]Net returns are returns to management, water and risk.

[c]Total land available is 3.7 million acres of which 2.6 million are irrigable.

Table 10. Expected Crop Output, Irrigated Acreage and Producer Net Returns for Alternative Natural Gas Prices, Texas High Plains[a]

Item	Unit	Price of Natural Gas per 1000 cubic feet										
		0.00	0.38	1.25	1.30	5.46	6.09	6.94	7.63	7.79	8.40	10.12
		1,000,000										
Net Returns[b]	dol.	331.8	319.0	291.0	289.6	160.5	141.1	116.2	99.3	95.9	92.4	87.6
Irrigated Acres[c]	ac.	2.6	2.6	2.6	2.6	2.5	2.5	2.1	1.6	0.4	0.2	0.0
Crop Output												
Corn	bu	180.8	180.8	180.8	180.8	180.8	180.8	180.0	180.8	47.7	23.3	0.0
Cotton	lb.	96.1	203.5	203.5	203.5	203.5	173.0	173.0	61.1	61.1	61.1	61.1
Grain Sorghum	cwt	45.6	32.7	29.3	29.3	29.3	29.3	12.0	12.0	12.0	15.3	15.3
Soybeans	bu	0.9	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	bu	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	30.3	30.3	30.3

[a] Source: Lacewell, Condra and Fish.
Based on a per acre $15 charge for land and no charge for water on acres irrigated. Crop prices are set at levels that seem most reasonable with current information. These prices are cotton $0.42/lb., cottonseed $100/ton, wheat $3.75/bu, soybeans $4.50/bu, corn $2.70/bu, and grain sorghum $4.25/cwt.

[b] Net returns are returns to management, water and risk.

[c] Total land available is 3.7 million acres of which 2.6 million are irrigable.

planning price levels for crops are presented in Table 10. With the higher crop prices, a much different picture evolves. Using a natural gas price of $1.30/mcf as a base (since it is the approximate current price in the area), producer returns to water, management and risk are $289.6 million with 2.6 million acres irrigated.

At a natural gas price of $5.46, net returns decline 45 percent, and irrigated acreage declines slightly as soybeans go out of production. The next major adjustment is near a natural gas price of $7.00, at which irrigated acreage declines to 2 million and net returns decline to $116 million (a 60 percent reduction compared to a $1.30 natural gas price). Grain sorghum and cotton production are also declining.

Irrigated production ceases at $10/mcf natural gas. Returns to management and risk are $87.6 million and cotton, grain sorghum and wheat are produced dryland. It is at this point that returns to water have been reduced to zero.

The results presented in Table 10 suggest that at the 1976 planning price level for crops, the Texas High Plains will continue to be a major irrigated region, even with rather dramatic increases in the price of natural gas. This is a regional conclusion, however, a deficiency of this analysis is the lack of consideration of internal adjustments that have little immediate effect on output but have significant implications for local farmers, financial institutions, suppliers and communities.

Average Farm Implication

Since the regional analysis glosses over important issues facing the individual farmer, an average farm firm was studied. For this analysis, an abundant water supply is assumed, all acres are irrigated and farm size is 700 acres.

The abundant water supply indicates this analysis applies to the most favorable irrigation situation on the Texas High Plains. Other areas have shallower wells, but well yields are less, due to a very limited saturated thickness. Alternatively, other areas have relatively more abundant groundwater supplies but pumping depth is much greater, hence, energy requirements for pumping are high. Therefore, it is expected that for other resource situations on the Texas High Plains, returns to water would be less than for the following situations, i.e., adjustments would occur at lower natural gas prices.

For this average farm situation, there was no charge included for land, water, management or risk. Further, the two sets of crop prices were identical to those used for the region.

Figure 9 shows total farm and per acre returns to land, water, management and risk for the average 700 acre farm. For the 1971-74 average crop prices, returns to land, water, management and risk is about $36,000 for the farm or just over $50 per acre at a zero natural gas price. At a natural gas price of $1.30/mcf, these returns decline to about $27,000 or just under $40 per acre. These data suggest that at $4.25/mcf for natural gas, all land will be farmed dryland since the fuel costs more than the water is worth in producing crops given the 1971-74 average prices for crops.

Compared to the 1976 planning crop prices, returns to land, water, management and risk are increased some two to threefold. At a natural gas price of $1.30/mcf, these returns are about $72,000 or just over $100 per acre. Returns continually decline to about a natural gas price of $8.30, at which all production is under dryland conditions.

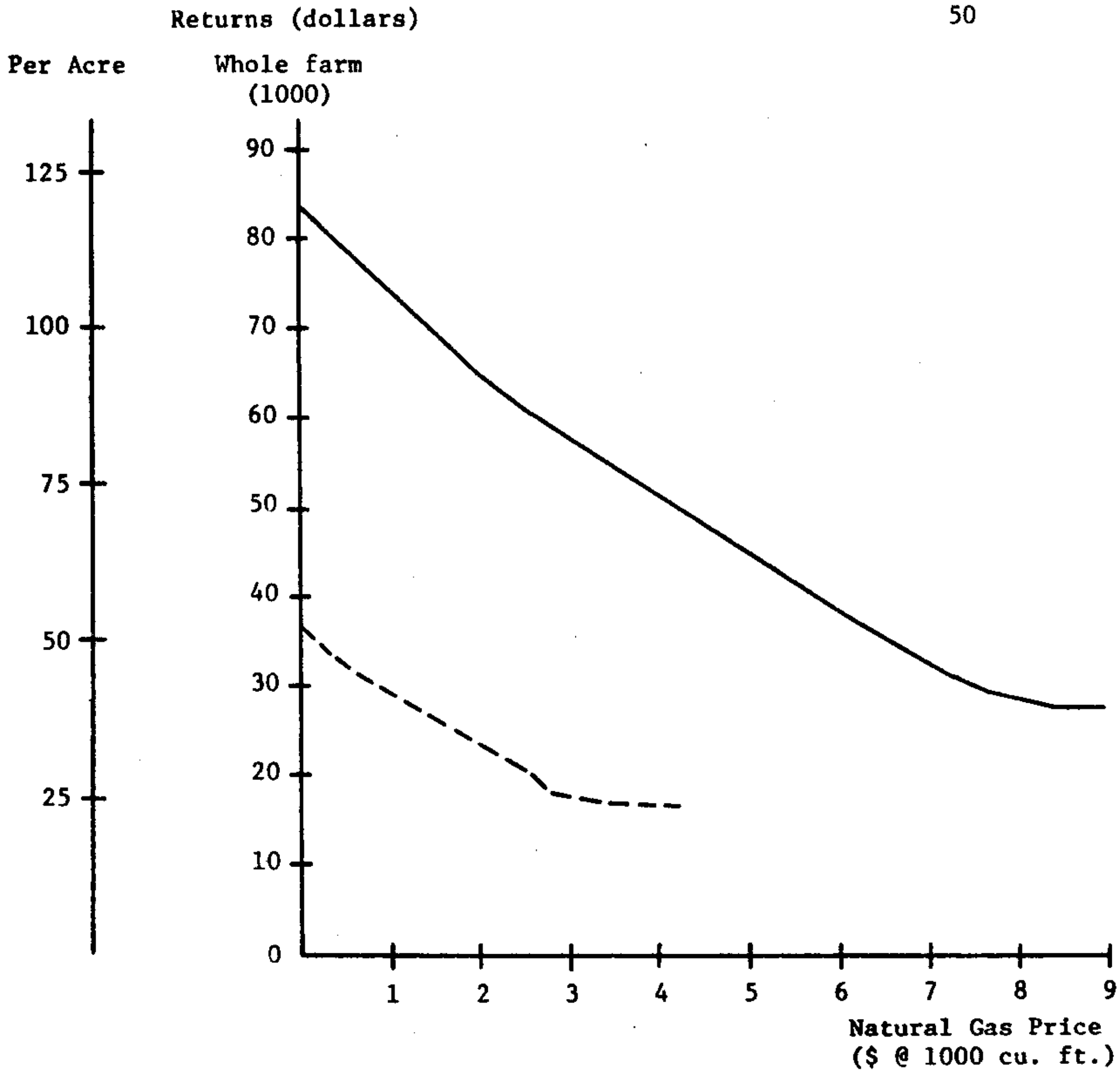

Figure 9. Returns to Land, Water, Management and Risk for a 700 Acre Irrigated Farm; Strong Water Supply in Texas High Plains[a]

[a]Assumptions Underlying the Relationships

Land and Water Charge (dol. per acre)		Crop Prices	
	Cotton @ lb.	$0.31	$0.42
	Grain Sorghum @ cwt	3.10	4.25
	Soybeans @ bu	4.27	4.50
	Corn @ bu	1.95	2.70
	Wheat @ bu	2.60	3.75
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Figure 9 can be used to estimate the maximum price for natural gas which a particular producer can afford given his lease or land payment and household expense requirements (returns to management). For example, assume a producer is purchasing the 700 acre farm and his annual principal and interest payment is $50,000. In addition, the producer requires a return for management (to cover household expenses) of $15,000. This means this producer must have $65,000 returns to land, water, management and risk. Therefore, going to $65,000 returns on the vertical axis and moving horizontally to the intercept with the solid line indicates the producer can pay up to $2.00/mcf for natural gas given the 1976 planning prices for crops. If natural gas price exceeds $2.00 the producer must either acquire more land at a lower price, reduce his returns to management (standard of living) or default on the land payment.

A similar example can be shown for the producer with a cash lease. Assume a cash lease of $70 per acre and required returns to management of $14,000 or $20 per acre. In this case, required returns to land, water, management and risk are $90 per acre. Moving up the per acre vertical axis to $90 and then across horizontally to the returns solid line again gives an upper permissible natural gas price of $2.00/mcf.

Other situations can be similarly analyzed. The analysis for the High Plains indicates the difficulties of addressing the adjustments expected with an increasing natural gas price. Agriculture is in a most dynamic era of changing crop prices, uncertainty relative to government policy, and varying input prices. One point that can be made is that natural gas price increases elevate the cost of pumping water and hence decrease the value of the groundwater. This effect can be expected to be reflected in land prices in the area. The average farm example serves to show the level of natural gas price at which a specified payment as annual purchase payment or cash lease as well as a given return to management can no longer be maintained. The cash lease must be reduced to keep land in irrigation. The farmer making land payments is in a particularly sensitive position; i.e., the net returns from the farm are not sufficient to make payments on land and meet household expenses.

Producers have traditionally invested a majority of their savings in land. As the residual returns to land decrease, land values will decline and producers' savings will be eroded. Thus, both the income generating and equity position of the producer are destroyed.

United States

A very ambitious study evaluated the effect of high energy prices on irrigated agriculture for the total U.S. (Dvoskin and Heady, 1976a and 1976b). These economists used a national linear programming model and estimated the effect of a doubling of energy costs. For discussion of regional implication, the U.S. is divided into seven regions; Northwest, Southwest, Great Plains, South Central, North Central, North Atlantic and South Atlantic.

In aggregate, the study showed that under high energy prices, Western regions would reduce energy use by much more than Eastern regions because of reductions in irrigated acres. Relative to resources used in agriculture, there would be an estimated reduction in irrigated land used of 12 percent, reduction in water used of 22 percent and reduction in natural gas used of 15 percent. These values are presented in Table 11. The primary region that reduces use of energy with a doubling of price is the Northwest.

Table 11. Effect of doubling energy costs on resources used in agriculture and regional farm income share.

Item	Unit	Base	High Energy Price	Percent of Base
Resources				
Dryland used	1000 ac.	320,707	329,026	102.59
Irrigated land used	1000 ac.	22,894	17,905	78.21
Total land used	1000 ac.	343,601	346,931	100.97
Water used	1000 ac. ft.	47,421	36,890	77.79
Natural gas used	1,000,000 Mcf.	180,060	152,966	84.95
Regional farm income share				
North Atlantic	percent	4.72	4.70	99.58
South Atlantic	percent	13.96	15.88	113.75
North Central	percent	46.90	47.98	102.30
South Central	percent	9.33	8.26	88.53
Great Plains	percent	16.35	16.05	98.17
Northwest	percent	2.29	1.68	73.36
Southwest	percent	6.45	5.45	84.50

[a]Source: Dvoskin and Heady.

According to Dvoskin and Heady, the relative productivity of energy in irrigated regions is smaller than in dryland regions. This means with high energy prices production would tend to shift from the irrigated regions of South Central, Northwest and Southwest to the dryland regions of the North Atlantic, South Atlantic, North Central and Great Plains.

Dvoskin and Heady extend their analysis to considering regional farm income changes with a doubling of energy prices. With high energy prices they estimate a reduction in irrigated acres and nitrogen use resulting in a smaller agricultural output. This would mean higher farm incomes. Table 11 shows the regional share of farm income and change associated with a doubling of energy prices. Although reduced farm output results in higher farm product prices and in turn higher farm income, it is not equally distributed among regions. The irrigated regions of the West would be relatively worse off and the dryland Eastern and Midwestern regions would be relatively better off.

Dvoskin and Heady suggest some possible cropping pattern adjustments such as corn tending to move from the West and the South toward the Midwest and cotton reversing the past trend from the South Atlantic to the Southwest.

These examples from Texas and the U.S. indicate that irrigation is vulnerable to increasing energy prices. In short, the picture appears somewhat gloomy. However there are opportunities for irrigated agriculture.

Responding to the Challenge

It seems important to emphasize some of the ways irrigated agriculture can respond to increasing energy prices. To begin, improved efficiency is essential. In Texas average pump efficiency was found to be about 52 percent, while natural gas efficiency averaged about 19 percent for 1968 (Ulich). Improving pump and engine efficiencies could result in a 41 percent reduction in energy used for irrigation in Texas (LePori and Lacewell). Similarly, Fischbach indicates that an annual savings of \$3.1 million would result by improving pumping plant efficiency in Nebraska.

Continuing with the efficiency plea, increased use of tailwater recovery pits or re-use systems is needed. Fischbach indicates that in Nebraska re-use systems could save farmers \$2.6 million per year in energy costs.

Essentially some long term solutions for irrigated agriculture lie in improved distribution systems and in reevaluating our crop production systems and developing new approaches. Relative to improved distribution systems, the agricultural engineers are making exciting progress. For example, Dr. Lyle of the Texas Agricultural Experiment Station is progressing rapidly with a moving drip system.

Regarding new crop production systems, it is much more difficult to find the really dramatic adjustments and new innovations. However, there are a couple of new cotton production systems developed in Texas that are a significant improvement in view of rising energy prices.

In the South Texas region a new irrigated crop production system was developed, based on short season cotton varieties and careful use of all inputs. For example, less irrigation water is applied to the new system as is less nitrogen and insect control is based on careful scouting of the field. The new system, compared to the traditional system, has a yield increase of about 40 percent, uses 33 percent less energy per acre hence a 56 percent reduction in energy use per pound of lint and reduced production costs of 43 percent or from 47.6¢/lb. to 26.9¢/lb. (Sprott, Lacewell, Niles, Walker and Gannaway).

With the drastic situation in the Trans-Pecos region of Texas, a new system had to be introduced rapidly. Using results from Texas Agricultural Experiment Station research at Pecos, the Texas Agricultural Extension Service developed a cotton production system and tested it in demonstration fields on cooperating producer's farms. Again the system revolves around a short season cotton variety. In this case irrigation water applied is being reduced from 40 or more acre inches to 30 or less. In turn, nitrogen use is reduced from 250 lbs./acre to 60 lbs. or less. With the reduced plant growth that results, the insect problem is greatly reduced and in fact typically no insecticides are needed with the new system. With the large reductions in inputs, a yield decline is experienced (from about 700 lbs./acre down to about 630 lbs./acre). However, the reduction in costs of production far outweigh the reduced yield and in the final analysis, the cost of producing lint with the new system is reduced from about $70¢/lb. to near 42¢/lb. (Condra, Lindsey and Neeb).

With irrigation costs expected to continue increasing we are entering a new ball game. Many of the past guidelines and rules of thumb are no longer applicable. Thus, we believe there is much at stake in the irrigated regions of the U.S. and research is a critical key to the future.

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